ECR ION SOURCE BASED LOW ENERGY ION BEAM FACILITY AT VECC

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Abstract

A unique, low energy heavy ion irradiation/implantation facility has been developed at VECC for materials science and atomic physics research. The facility utilizes the indigenously developed 6.4 GHz ECR ion source, which was earlier being used to inject heavy ions into the room temperature cyclotron at VECC, Kolkata. The facility provides a unique tool for surface modification in materials, by a broad range of high charge state ion species like N, O, Ne, Ar, Kr, Xe, Fe, Ti etc. It can deliver ion beams up to a few micro amperes at an energy of 10 keV per charge state, enabling to generate high defect densities i.e. high value of displacement-per-atom (dpa). The beam energy can be further enhanced by keeping the target floating at a negative potential (up to 25kV). The ion beam is focused to a spot of about 2 mm diameter on the target using a glaser lens. A magnetic X-Y scanner is used to scan the beam over a target area of 10mm x 10mm for uniform implantation. The sample chamber has provision for mounting multiple samples on indigenously developed disposable beam viewer for in-situ beam viewing during the implantation.

INTRODUCTION

In present day Materials Science Research, studies with thin films are of immense importance both from basic physics as well as from applications point of view. Exotic physics comes out from defects and disorder in two dimensional systems. Hence, charged particle irradiation brings forth enormous novel phenomena in thin films. In this context, low energy (hundreds of keV) heavy ions from ECR ion source are ideal tools for generation of tailor made defects in thin films. The low energy nuclear projectile experiences significant energy loss through collisions in the target and its range may vary up to a few hundred nm. This causes an enormous generation of point defects through the so called nuclear energy loss in addition to the significant inelastic energy loss. Low energy ion beams also provide a controlled means for modifying material surfaces for achieving desired properties.

THE FACILITY

A low energy heavy ion implantation facility as shown in Figure 1, has been developed at VECC using the indigenously built 6.4 GHz ECR ion source [1-3]. The ion source was designed to meet the injection parameters of the cyclotron and it operates with the maximum extraction potential of 10 kV thus delivering ion beams at a maximum energy of 10 keV per charge state. The ion beam extracted from the ECR ion source is q/m analyzed by a 90^o analyzing magnet. The analyzed beam is optimized on a retractable type Faraday Cup through 8x8 mm slit.

The details of the experimental setup are shown in Figure 2. The mass analyzed ion beam is focussed by a magnetic glaser lens on the target film. Figure 3 shows the beam optical simulation. Figure 4 shows the photograph of the beam spot seen on a beam viewer. The observed beam spot size (2mm dia.) matches with the simulated value The experimental chamber has a sample manipulator with an arrangement for mounting multiple samples. Each sample sits over a disposable type indigenously developed low energy beam viewer for viewing the beam during implantation (Figure 5). Provision has also been made to float the sample at –25kV for the enhancement of ion energy. While the sample is floated at a high voltage, the beam current is

Figure 1: Layout of ECR-based Low Energy ion Beam Facility

measured by an indirect method. The total fluence is estimated by integrating the beam current over the entire implantation time. With a recently procured multi-facility sample chamber, the beam energy can be further enhanced to 60 keV per charge state.

Since the irradiation/implantation is motivated for the modification of the properties of materials with proper understanding of the mechanism, it is essential to have uniform irradiation over the target area as well as the thickness. Uniform irradiation along the thickness is guaranteed by thin films. But to have uniform irradiation over the whole area of the sample, it is necessary to scan the beam over the target surface, preferably with very low time periods (i.e. high frequency) compared to the irradiation time. With this end in view, a magnetic type ion beam scanner has been designed and developed to facilitate uniform implantation over the entire target area. It has two sets of coils to produce a linearly varying magnetic field up to 500 Gauss. The magnetic field can be fixed at any value depending upon the ion species and the beam energy. The stability and the linearity of the current ramp creating magnetic field are controlled with the help of feedback loops used in the circuits. The mean values of the line and frame frequencies are 0.5 Hz and 15 Hz respectively.

Initially the ion source was developed to produce ions of the gaseous elements. However, due to the requirement by materials science users of this facility ion beams of S, Fe, Ti and Hf have been developed using the MIVOC technique. In this method the source material is usually an organo-metallic compound containing the element for which the beam has to be developed. We have observed that for obtaining good yield the vapour pressure of the compound should lie between 10 to 0.1 Torr at room temperature. A dedicated set up has been developed for this purpose which has the pumping and vacuum measuring facility of its own. The entire MIVOC setup is electrically isolated from the ion source, which enables its operation at ground potential. The vapour of the MIVOC compound is injected into the ion source using an electro-mechanically operated sapphire seal valve. With this arrangement it is possible to optimize the ECR parameters for the desired ion species. We have observed that for certain ion species a suitable mixing gas is essential for improving the required beam yield.

Using this facility several ion implantation experiments have been carried out. Some of the experiments carried out using this facility were aimed at simulating very high dpa (displacement per atom) in nuclear structural materials. Because of the availability of very high currents from this machine (~10μA) such experiments could be carried out successfully. In addition to this, implantation experiments on semiconductors, organic semiconductors [4], organic single crystals for non linear optics etc have been carried out. Users from universities, BIT Mesra, IIT Rorkee, BARC and VECC have utilized this facility for carrying out several successful experiments. Some up-gradations planned for the facility in the immediate future are development of in situ heating or cooling of the sample during the implantation and installation of sample temperature profiler. There are plans to setup a separate beam line exclusively for surface physics experiments.

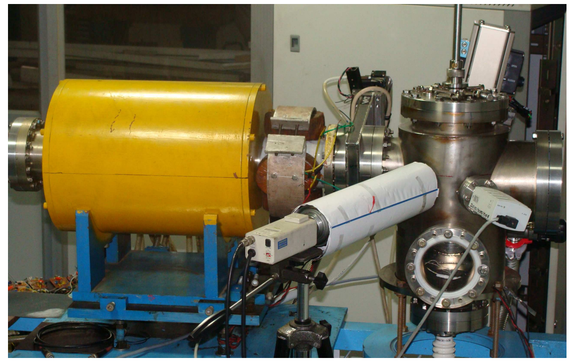

Figure 2: Implantation Setup.

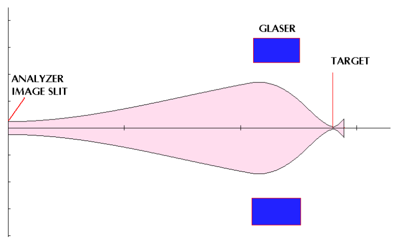

Figure 3: Beam transport simulation.

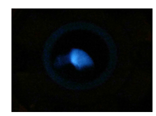

Figure 4: Beam Spot seen on the viewer

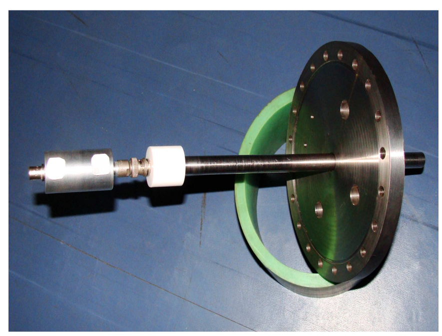

Figure 5: Target Ladder Assembly.

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